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MISSION SENSITOMETRY

Definition:

Sensitometry refers to the technique(s) of applying a series of known, controlled exposures to photosensitive material such that, after subsequent processing and density measurement, a calibration curve of output (density) versus input (exposure) may be generated. This curve is the "characteristic curve" of the material and is usually plotted as density versus log exposure as suggested by Hurter and Driffield.

Scope:

This discussion will deal with several proposed ways of applying sensitometric exposures to the actual film used in a reconnaissance mission. It will discuss the goals to be achieved and the advantages and disadvantages of the methods.

Present Practice:

It is normal practice with mission film to attach a sensitometric strip exposure at the head and tail of each roll before processing. These sensitometric exposures are on the same type film as the mission and comparison of the H & D curves from head and tail with the specified standard curves provides a measure of machine stability for the over-all mission.

A piece of film from the actual mission roll is also taken off before final loading in the flight vehicle and returned to the processing sites for a third check of mission sensitometry. This provides data on the characteristics of the actual film in flight before it undergoes flight environment.

Proposal:

It has been proposed that sensitometric exposures be placed frequently along the edge of the mission film. Such exposures could be applied at one of three possible times:

1.) Prior to or during spooling at the film manufacturer's plant.
2.) During flight in the vehicle, or
3.) On the ground just prior to processing.

These are the three times when the film is being spooled (or unspooled) and all of the edge would be accessible.

Analysis of Point of Application:

1. Application at the manufacturing plant.
This location has both technical and economic disadvantages. On the technical side, the film is being transported faster here than anywhere else in the system. For many reasons it would be ideal to make the controlled exposures on stationary or slowly moving film and to accomplish exposures at the maximum transport speed reduces the reliability and accuracy of the result.

Furthermore, to attempt to vary the speed or stop the film in the spooling operation would jeopardize the uniformity of winding tensions in the roll. This greatly reduces the reliability of film handling and tracking in the camera, and has been known to contribute to serious camera malfunction.

The costs would also be increased out of proportion. The exposures would have to be applied to all material, yet only a small portion would become flight material. The balance of the material would be raised in cost without serving any useful purpose.

2. Application in-flight.
This has the real advantage of being applied at the same time and under the same environmental conditions as the scene image exposure. However, it would violate the general principle of keeping complexity on the ground and simplifying the airborne equipment whenever possible. The need for "controlled" exposures dictates accurate light source intensities, stable power supplies, and constant exposure conditions. These are not always compatible with vehicle environments and with the variable transport speeds required for operational (IMC) reasons. Since the feedback from an airborne sensitometer is inadequate to certify the "control" of the exposures and since post mission return of the device is normally impossible, it would be entirely **unsatisfactory** to attempt to rely on in-flight exposures for monitoring ground operations such as processing. However, in-flight exposures would serve the useful purpose of providing data on the film sensitometry at the time of scene image exposure.

no problem put on head & tail as presently done

3. Application on returned flight material.
The most logical place for applying such exposures would be at the head end of the processing machine, just prior to processing. Here the film is moving slowly, at a constant speed. The equipment could be as bulky as necessary for stability and the edge exposures would be added only to actual flight material.

These exposures, however, would not monitor any changes of the film sensitometry during flight.

On the basis of these considerations, it appears most reasonable to add edge exposures on the ground just prior to processing, if the exposures can be shown to serve a useful purpose. This is the next question to explore.

Purpose of Edge Exposures:

The reasons for proposing edge exposures generally fall into three categories:

a.) To check on the processing (or film) variations throughout the mission roll.

b.) To facilitate post processing measurements such as edge traces, haze measurement, etc., by having local density patches available for reading by the same microdensitometer, and

c.) To check on possible variations in film sensitometry due to actual flight environment of temperature, pressure, humidity, etc.

Analysis of Purpose:

Purpose (a) sounds like a reasonable goal on the surface and there is no doubt that more frequent sensitometric data would aid in confirming the mission processing profile. However, let's examine the type of variation most frequently encountered. Deep tank machines or spray machines not designed and maintained for high quality processing can most frequently produce mottle or streaking. If such processing variations occur, they appear as density variations in both directions of the film surface. Sensitometric exposures along one edge (perhaps every 18 inches) would show only long trends along that edge and would have no use in monitoring across the web variations.

In actual fact such short term variations seldom exist in a high quality processing lab unless some component malfunction occurs, and if they did exist, edge exposures would be of questionable value in monitoring the fault.

Long term trends during a mission roll are checked now by sampling and photographically testing developer solutions for every 1,500 feet or less of mission material. These results, plus the head and tail tests give a good long term picture of trends throughout the mission. Typical results are shown in Figures 1, 2, 3, 4, and 5. In addition, a tape record of processing level and IR densitometer reading versus mission footage is automatically recorded as a record of the mission processing profile.

Thus if processing data were the only reason for edge exposures, there would exist a serious question of whether the additional data gained would be worth the added complexity.

Reason (b), to aid in post processing measurements has been brought forward only recently as the result of the interest expressed by the committee in the general technique of edge traces for quality measurement. These traces require calibration of the micro-densitometer used to measure the edge density profiles and it is convenient and accurate to have a gray scale of known sensitometry available near the scene edge being measured. It is also possible that other useful measurements of scene haze, or system flare can be assisted by such edge exposures. These edge exposures, of course, could not be analyzed should there be some extraneous source of exposure present such as static, fog, or radiation.

Present day mission material is not routinely analyzed for such data. If it is felt that time, man power, and justification for such data will all be available in the future, then sensitometric edge exposures may be a useful adjunct to the data collection and analysis.

Reason (c) to provide information on effects of flight environment, can only be accomplished by in-flight exposures. The existing ground test data on sensitometry at varying temperatures and pressures, would not lead to a serious concern over changes in film sensitivity in-flight compared with ground data. Our present knowledge of actual temperature, pressure and humidity of the film at the time of exposure is woefully inadequate. As a result we cannot say conclusively that ground tests have been made under flight conditions, because "flight conditions" are not really defined.

However, ground tests have bracketed flight conditions and show no reason for concern at low pressures and changing temperatures.[1] Neither has operational mission film shown symptoms that would lead to the suspicion of changing sensitivity with environment.

Thus reason (c) raises a question that is not considered very serious on the basis of ground test data. To answer the question requires adding complexity to the airborne equipment and it is not recommended until such time as ground or flight data indicate that a problem exists.

Summary:

The discussion above has presented a rational position on sensitometric edge exposures on mission material from the standpoint of film manufacturer, camera designer, processor, and user. In weighing the problems of each organization, the following matrix summarizes the ways in which the goals can be satisfied.

[1]Manual of Physical Properties, Section 16, Practical Behavior, p. 6:
"The low humidity, the reduced pressure or the cold temperature at the time of exposure had no significant photographic effects. At the higher temperature slight speed losses amounting to less than half a lens stop were observed. ...."

Point of Application	Purpose a	Purpose b	Purpose c	Relative Complexity
1	No	Yes	No	High
2	No	Yes	Yes	Medium
3	Yes	Yes	No	Low

Satisfaction Matrix

From this, it appears that applying exposures on the ground before processing accomplishes purposes (a) and (b) with relatively low complexity. Purpose (c) can only be accomplished by in-flight sensitometry and this complication is not recommended at this time.

On this basis the following conclusions can be supported.

1. There is some, but very little, to be gained by adding edge exposures solely for processing data.
2. Edge exposures would be of use in scene image data collection and analysis.
3. They would also be of use in monitoring any effect of in-flight environment on sensitometry.
4. The only way to get a complete picture is to apply two sets of exposures, one set applied in-flight, and a second set applied just prior to processing, but only the latter are recommended at this time.
5. The value of such exposures must be weighed in terms of the following pros and cons.

Advantages

1. Provide more frequent sensitometric data.
2. Aid in confirmation of mission processing profile.
3. Aid in establishing ground rules for scene luminance calculations for particular sections of mission record.
4. Aid in determining flight environment effects.

Disadvantages

1. Increase risk of fogging material (during edge print).
2. Complicates both camera and ground equipment without providing additional sensitometric process control, i.e. all information is post facto to processing.

3. Slight edge fog from other sources could shift sensitometric results and provide misleading data.
4. Could conceivably obliterate edge data (timing track, fiducials, etc.) if any of the exposures in question were misoriented.
5. Uniformity in processing is most difficult to control near the extreme edge. Currently this is of little consequence, however, if edge printing were used, uniformity at the edge would become important and could produce misleading results.

A preliminary specification for a sensitometric edge printer for processors was prepared and submitted under an existing contract in October 1963. To date, no approval or rejection of this approach has been received.

AT [redacted]

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CM MEASUREMENT PROGRAM

1. GOAL

In reviewing the analytical model used to evaluate CM performance, the ground test and launch preparation procedures employed [redacted] in Boston, [redacted] in Palo Alto and at the launch site at Vandenberg, the in-flight instrumentation records and the photographic product, it is not obvious that system performance is different in orbit than has been measured in the laboratory. There exist, however, several areas where available data ~~is~~ are inconclusive or incomplete, and analytical studies have not been performed in sufficient detail or adequate precision is not possible to permit definite conclusions to be drawn. It is recommended that activity in the measurement program be concentrated in these areas of suspicion and that adequate analytical studies be undertaken to properly support the measurement program. Much of the necessary data can be obtained by ground testing in the laboratory or in thermal/altitude chambers, and wherever possible this course should be pursued in preference to on-orbit measurements and tests. It is obvious, however, that laboratory simulations are not exact and in some cases (e.g. zero "g" environment) impossible. For this reason it is necessary to support and verify the results of ground tests by limited satellite testing. Measurements of this nature have been considered only in cases where they can be obtained with little or no effect on the operational employment of the system. The role of aircraft tests (possibly using the 112 system) is not entirely clear in view of the radically different operating conditions (camera cycling rates, thermal environment, stability of platform, vibration environment), however it is likely that useful data concerning film/filter combinations, effects of haze etc. might be obtained in this manner. Since aircraft testing tends to be more attractive in terms of economy,

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availability of accurate data, and has no impact on satellite operations this approach has been given consideration in each area in preference to satellite testing.

2. ASSUMPTIONS AND PRELIMINARY CONCLUSIONS

In order to identify and segregate those areas where additional work is indicated it is useful to point out a number of preliminary conclusions reached by the committee on the basis of data presented to the committee or as the result of detailed study of Cm photography.

2.1 Vehicle Motions

Precise data describing vehicle orientation and vehicle rates in roll, pitch and yaw are available during photographic passes from the horizon cameras and from the stellar/index camera carried on Cm flights. In addition telemetered data relating to guidance system performance are available during each pass over tracking stations, and on a few flights where a tape recorder was carried, during photographic passes as well. The data contains some inconsistencies which have not been explained, but in general good agreement exists. Although in isolated instances large attitude errors and vehicle rates have been observed and measured, these instances in general have been related to malfunctions or failures in the attitude control system and should not be employed to describe guidance system performance under nominal conditions.

Attitude data have been examined in detail during photographic passes for a number of Cm flights and in general vehicle rates are well under 30^{o}/hr. abour each axis. Angular excursions are generally well within the specified dead-band limit (this limit varies somewhat from flight to flight, has been decreased to $\pm$ 0.5^{o} recently, but in no case is larger than $\pm$ 3^{o}). Converting these angles and rates into equivalent image smear at ground scale is straight forward and the

maximum smear contribution from this source is on the order of one foot or less (one foot of image motion results from approximately 70°/hr. pitch rate for instance). On this basis it has been concluded that vehicle attitude and rates is not a problem of existing Cm photography and that confirmation by means of special experiments or measurements is not necessary in this area. It is recommended that existing measurements and evaluations be continued, and that additional tape recorded telemetry data be obtained to support the evaluation and to explain inconsistencies and biases remaining in the data.

2.2 V/h Mismatch

In the Cm system along track image motion resulting from vehicle velocity over the earth's surface is compensated by translation of the camera lens in a direction which tends to hold the image fixed with respect to the film during the exposure interval. Since slightly elliptical orbits are flown, velocity and altitude over the ground vary from point to point on the orbit. A small V/h programmer is used to provide means for selecting a given V/h variation (ramp) over a photographic pass. The desired variation for perfect match is generally sinusoidal. Early Cm payloads used a system of linear ramps, more recent flights have employed a system of sinusoidal ramps capable of closer match to the desired V/h profile. Selection of the desired ramp is by ground command.

In some flights V/h mismatch has been larger than desirable as a result of thermal effects and inaccurate ephemeris early in the flight. Available data indicates that during normal vehicle operations it has been possible to match V/h over the complete photographic pass to better than 3% and during most passes to within 1%. A 3% mismatch contributes approximately four feet of image motion under nominal

exposure conditions).

On the basis of existing evaluations the committee has concluded that V/h errors contributions to system degradation are well understood; straight forward, analytical techniques are available to predict effects of such errors and that no additional testing or measurement program is necessary in this area.

2.3 Exposure

Exposure of the film in the Cm camera is accomplished by moving a slit over the format area; exposure time is thus a function of the slit width and its velocity over the format. No capability for varying slit width in flight exists; the width to be used on a given flight (generally 0.20 or 0.25 in.) is selected prior to launch on the basis of illumination predictions. These predictions are made on the basis of time of year, orbital parameters, time of day predicted for launch. Exposure time in orbit thus depends upon velocity of the slit, which is a function of camera cycle time and which in turn is tied to the V/h program being used for proper image motion compensation. Thus actual exposure times vary somewhat in orbit, and in a manner which is not optimum, that is exposure time is proportional to V/h and is not directly related to illumination levels. The way in which exposure varies however seems to be well understood; a compromise has been reached wherein non-optimum exposures are compensated ~~in the develop- exposures are compensated~~ in the development process (three levels of development are available) in order to retain the advantages of simplicity and reliability in the airborne hardware. It has been generally concluded within the committee that no significant degradation results from this compromise under average illumination conditions.

Under some operational conditions (strong desire to attempt coverage of a high priority target under marginal illumination) it is clear that capability for varying exposure times in-flight would be beneficial. It is felt that the exposure situation in general requires no additional in-flight measurements to explore degrading effects, however it is recommended that the decision to avoid in flight exposure control be re-examined and that aircraft tests under marginal illumination conditions might be beneficial in determining the level of sophistication necessary in such a device.

2.4 Uniformity of Quality

As a result of examining large quantities of Cm photography the following general observation has been made and is stated here as an assumption in evaluating a measurement program: there seems to be no significant variation of quality within given frames of Cm photography; with specific exceptions, quality tends to be quite uniform within a frame. Exceptions have been related to tolerance build up in the data block area under abnormal thermal conditions and probable emulsion accumulation on the rail surface. As a result of this observation it can be concluded that variations in film flatness over the format represent no problem in flight and no in-flight measurements relating to film flatness are recommended at this time. Pre-flight measurements in the laboratory (Aschenbrenner Test) are used to verify flatness within tolerances which are tighter than depth of focus. It is felt that this test along with the observations discussed above provides ~~adequate~~ confidence that film flatness is maintained within adequate limits under orbital conditions.

In view of the difficulties associated with in-flight Aschenbrenner tests and the probable adverse effects on operational coverage, it is recommended that in-flight tests of this nature be held in abeyance pending results of related tests.

2.5 Focus Shifts

A ~~second observation which has been made as a result of examination of large quantities of Cm photography is that a definite indication of focus variations appears to exist.~~ ~~This~~ An observation relates to a general "softening" of the image in areas where no obvious weather problems exist and the quality is below that observed in other portions of the mission. Of immediate concern when pursuing focal shift problems are the areas of (a) thermal environment in orbit, its predictability, how well it has been measured, and its effects on lens distortions and/or focal shifts and (b) vibration encountered within the exposure interval. In examining the analytical and experimental results which have been presented in both of these areas, the committee feels that the data are inconclusive, at best, and that a thorough measurement program should be undertaken in order to explore in detail the extent to which these factors are degrading the photography. The bulk of the measurement program being recommended bears on these areas.

2.6 Other Degrading Effects

It is obvious that the corona problem is a very serious one in Cm and that high priority must be placed on a program leading to a solution to this problem. It is highly probable that a larger proportion of photography is affected than that which is obviously "corona marked" and this factor should be considered in arriving at a solution.

An impression that a fairly high percentage of Cm photography is affected by light leaks has been expressed by committee members. In most cases these light leaks are related to malfunctions (horizon shutter failure, light-tight hoods failing), however a significant number of frames in a normal mission are light struck as a result of film sitting between photographic passes in an area where it receives stray light within the payload. Since the possibility for some system improvement exists, this situation should be re-examined.

3. RECOMMENDED MEASUREMENT PROGRAM

In the course of various briefings and discussions a number of situations were described where inadequate data appear to exist in critical camera areas and which as a result tend to be areas of suspicion. These areas of suspicion tend to be grouped in three areas (a) behavior of the film as it is lifted from the rails by the scan arm (under range of environmental conditions encountered in orbit) (b) thermal environment of camera, especially the optical system proper under orbital conditions (c) vibration environment and characteristics of the camera system. In each of these cases it is recommended that sufficient testing and measurements be accomplished to confirm or discount them as a source of severe photographic degradation.

3.1 Film Behavior During Exposure

During its testing cycle in Boston, each camera is subjected to a test for film flatness during the exposure interval. The testing technique (Aschenbrenner test) employs a pair of small lamps mounted near the end of the scan arm and a series of five slits mounted in the scan arm at the position of the exposure slit (the five slits are parallel to the direction of scan). Each slit thus produces a pair of parallel lines (one line from each lamp) on the film during the scan, the distance between the lines at any point is a measure of distance from the slit plate to the film surface at that instant. From this data contours are plotted. The test is thus an accurate relative measure of film flatness with respect to the slit plate. It gives no measure however of focal shifts or of dimensional changes in the scan arm.

The Aschenbrenner test has been employed to measure improvements achieved in evolving the presently used four roller scan head from the two roller head previously employed. The test has been run only at room temperature and it is felt that a series of runs should be made, at

least in a representative system, over a range of temperatures. In addition measurements should be made over the range of film tensions likely to be encountered in orbit.

A second test technique was described [redacted] which employed a grid on the film itself. This grid was photographed using a fast exposure time ($\frac{1}{5000}$ sec.) at the moment the scan arm passed and was used to study the dynamic behavior of the film (including longitudinal and lateral motion). The test was used in the past with the two roller scan head and it is felt that it should now be repeated with the four roller head to be certain that no change has occurred in this area.

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3.2 Thermal Environment

The equilibrium temperature of the Cm payload on orbit is controlled by passive techniques which involve careful selection and application of surface finishes. In general two surface coatings of known α/ϵ characteristics are applied in an alternating pattern which varies from flight to flight depending primarily on the angle β between the orbital plane and the earth-sun line (solar angle). In this manner the average payload temperature is held within $70 \pm 10^{\circ}$ although skin temperatures vary over wider ranges. No active temperature control devices such as heaters or shutters are employed in the existing system, and it has been suggested in committee discussions that such devices might be necessary for more precise control. More data is needed before definite conclusions can be reached on this point however.

The precise thermal environment encountered in orbit by the camera optical system is dependent to a large extent upon the geometrical relationships within the system. A short description of the camera operating cycle is necessary to appreciate the significance of these

relationships. While the scan arm executes a back and forth motion in the "scan and return" cycle, the lens rotates continuously, being mechanically locked to the scan arm drum and barrel during the active portion of the scan. During this active scan the lens "sees" the ground through an opening in the drum. Once uncovered by blowing off a door during ascent into orbit this opening is uncovered throughout orbital operation and of course is always located in line with the scan arm (the lens is aligned only during the active portion of the scan in general). A command for camera system shutdown can be accepted at any time during a cycle, and once commanded the camera coasts to a stop; no braking is applied and no specific "rest" position is defined for the lens or scan arm. The "rest" configuration varies depending primarily upon the cycle rate prior to shutdown command (which is a function of V/h). In the rest position the lens is not aligned with the scan arm or with the opening but lies generally horizontal. Glass elements can be seen through the opening only at grazing incidence. In this configuration one side of the lens barrel "sees" the earth through the opening and thus tends to cool off during "rest" period the other side "sees" the 70 degree interior of the barrel and scan arm. The rest position of the scan arm is generally near the end of scan, and since the two cameras are rotating ~~as~~asynchronously in opposite directions, typically one scan arm comes to rest near one side of the payload skin the other scan arm near the other side. In general (other than noon orbit) one side of the payload is hot (exposed to the sun) the other cold (exposed to space).

3.2.1 Analytical Treatment

In the past rather rudimentary thermal models have been employed in selecting thermal patterns; a more sophisticated model

is being generated at present using techniques which have been proven in various Agena programs. The method is a nodal analysis using electrical network analogies in which items of hardware (black boxes) acting as sources or sinks form nodes and are coupled to adjacent nodes. To verify the results of such an analysis in a test program it is important that the location of instrumentation be selected on the basis of this nodal model.

The thermal model being generated for the Cm system tends to treat the critical camera components in a somewhat superficial fashion i.e. the lens is treated as a single element, as are several related components. It is felt quite strongly by the committee that the thermal analytical work needs to be extended into much more depth in the camera system proper. A detailed analytical model is needed which will permit estimates of longitudinal, radial and peripheral gradients within the lens assembly itself, for example, under varying orbital conditions and under the various conditions of system geometry which are encountered in operation. This is especially significant in view of the unpredictability of the "rest" geometry.

measurement more impt than model

3.2.2 Altitude Chamber Testing

Each Cm payload undergoes a fairly comprehensive series of tests prior to launch under simulated orbital conditions in a thermal/altitude chamber. As presently performed these tests are not primarily diagnostic but serve the function of certifying the flight worthiness of the payload. No attempt is made to monitor focal shifts nor is the camera system adequately instrumented for detailed diagnostic results.

Because of the lack of detailed analytical work and test data, it is strongly recommended that a comprehensive thermal measurement program be pursued on Cm, concentrating on thermal response of the optical system under a range of orbital conditions. Means for correlating these thermal effects with system photographic performance, either by means of a collimator used in conjunction with the thermal/altitude chamber or by means of auxiliary devices capable of monitoring focal shifts and similar effects. Such a device has been suggested and is described in a later paragraph.

To provide adequate data for exploring the desired goals of the program, thermal/altitude chamber tests should satisfy a number of criteria, most of which are not being met by present procedures for thermal testing. These criteria are enumerated below:

(a) Tests should be run under the best available simulated orbital conditions and over a range of orbital conditions likely to be encountered by future Cm flights. Present testing restricts individual payloads to the nominal condition predicted for that particular payload.

(b) The test specimen should be representative of the flight article and should be sufficiently complete in terms of auxiliary and related hardware items that the camera is exposed to as precise a simulation as possible. All camera doors should be removed and/or proper simulation of this aspect of the environment be provided.

(c) The orbital operations of the camera system should be programmed fairly precisely. As an example a typical range of cycle rates should be employed to be certain that

measurements are obtained over a representative range of camera "rest" configurations.

(d) Additional temperature sensors need to be provided, especially in areas critical to optical performance and in particular on the lens assembly proper. Attention should be paid to accuracy of the instrumentation and proper calibration procedures should be developed to provide confidence in the data. It has been reported that self heating effects degrade the accuracy of existing instrumentation, particularly on the scan arm; this situation should be rectified. Since it is important that thermal test efforts be correlated with the analytical model and these two efforts tend to be complementary, care should be taken to install sensors at or very near to points corresponding to nodes in the analytical model. Finally, since final confirmation of both analytical and measurement efforts requires special thermal instrumentation on a representative sample of orbital flights, the instrumentation system developed for the altitude chamber program should be qualified for use on operational flights.

(e) As mentioned previously, it is highly recommended that camera focal shifts be monitored during the thermal testing, since this is the area of primary concern. Ideally such monitoring would be accomplished by testing in a facility where combined collimator altitude/thermal chamber programs can be accomodated. Since very few such facilities exist,

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they are not completely operational and need to be modified to accept the Cm system, and since attendant problems such as scheduling, cost and security are very severe, it is felt that the use of such complex facilities should be avoided if other techniques can be substituted. One possible technique has been suggested by [redacted] STAT

[redacted] The suggestion represents an adaptation of a system successfully used on a similar optical system. Installation in Cm would involve mounting a light source (and probably a 45° mirror) on the scan arm in the approximate location of the light sources now used in the Aschenbrenner test. In addition two small prisms would be located at the front element of the lens, and the system arranged in such a way that images of the single source formed by separate rays through the two prisms would be coincident at the focal plane when the camera optical system is in focus. Any out of focus condition (changing lens focal length, changing the distance to the focal plane) would thus result in non-coincidence of the images, the distance of separation being measure of the focal shift. To avoid obscuring the format area, especially for use in orbit a small slot can be cut in the rail area and the lamp imaged at this point.

(f) To define the situation more completely, the possibility of running Aschenbrenner tests concurrently on representative frames should be examined. With this combination (film flatness and focal shift determination) it should be possible to tie down the major critical areas of the focus situation.

3.2.3 On orbit Measurements

Since ground test work represents, at best, a good simulation of the orbital environment, it is important that sufficient measurements of a diagnostic nature be obtained from operational satellites to support and confirm the results of ground testing. A limited amount of thermal data is available at present from each flight, including some tape recorded data; by expanding this existing instrumentation system the desired data should be obtainable.

In evolving an in-flight program the following points should be emphasized:

(a) Properly calibrated thermal sensors are required in locations consistent with the analytical model.

(b) Sensor accuracy should be selected on the basis of the desired diagnostic results.

(c) Attention should be devoted to good installation practice and self heating effects; special techniques may be required for sensor application to glass surfaces.

(d) The lens assembly, including glass elements must be adequately instrumented to obtain information on radial, periphal and longitudinal grandients.

(e) Tape recorded telemetry programming should be extended to provide better coverage of operational camera passes.

(f) To relate temperature profile to the camera "rest" configuration between various operational cycles it may be appropriate to monitor by some means the precise position of the scan arm and lens between camera passes.

Consider in-flight measurement of focus

3.3 Vibration Environment

Insufficient data exists at present to permit definite conclusions to be drawn concerning the role of vibration in Cm performance and the extent to which resolution is degraded (if at all) by vibration under orbital conditions. Such vibrations are present to some extent, being excited by camera operation and/or by vehicle moving parts; no precise measurements of the magnitude of this effect have been made. A difference of opinion (whether or not resolution is degraded by vibration) exists in this area partly on an intuitive basis and partly on the basis of limited and somewhat ambiguous data.

The most straightforward approach for removing doubts and clarifying the role of vibration appears to be a direct comparison of the static and dynamic resolution of the camera under closely simulated orbit conditions and over a representative range of operational programs. Such comparisons have been attempted on one or two occasions in the past but results are inconclusive. Two major problems appear to exist in running such a test on existing equipment. First the collimator normally used for resolution measurements has no provision for static resolution, nor does the camera system provide a straightforward means for such measurements. Second, and probably more fundamental is susceptibility of the collimator itself to vibration effects and the difficulty in distinguishing between camera and collimator degradations. A third shortcomings, related to these two, is the inability to obtain measurements while the orbital vehicle is completely assembled i.e. resolution tests are "payload only" tests with the payload rigidly fastened to the collimator base. No tests have been made with payload mounted on the Agena vehicle or a simulation of this configuration, nor have any resolution measurements have obtained while attempting to simulate vehicle induced vibrations. (It should be noted that such

excitations are quite small, probably the most severe being attitude control system gas valve firings on the aft rack approximately twenty-feet from the camera. A single valve provides 0.5 lb. thrust, is open for 20-30 m.sec., firing rate varies over a range of 5 to 15 pulses per second and typical operation of the system involves periods of fairly intense gas valve activity separated by varying periods i.e. up to several minutes, of little or no activity.) Little consideration, either analytical or experimental has been given the role of these excitations in past vibration studies.

A further factor which tends to make existing data inconclusive is the standard method of obtaining resolution measurements with the Cm system on the collimator. In test runs ~~of this sort~~ only the lowest camera cycling rate is used, and this is almost certainly the least severe mode so far as camera induced vibrations are concerned. This cycle rate is less than half that typically encountered in orbit. In addition a special test slit is used (.062" wide in contrast to the 0.20" to 0.25" typically used operationally) which has the effect of shortening exposure times, even at the slow cycling rate, to approximately 1/3 to 1/4 that typically encountered in oribtal operation. (Collimator resolution tests are typically made at 1/500th to 1/600th sec.).

3.3.1 Vibration Measurements

It is recommended that emphasis be placed on developing a technique which can be used with confidence to obtain a direct measure of static vs. dynamic resolution. The technique should, so far as feasible, meet the following criteria:

(a) The camera system should be mounted in a manner which closely simulated the orbital configuration.

(b) Camera cycling rates, exposure times should be varied over the range likely to be encountered in orbit.

(c) Tests should be run with those excitations present which are likely to be experienced on orbit (or a reasonable simulation)

(d) Wherever feasible collimator effects should be determined and factored out.

If, as a result of the static-dynamic comparison, a significant degradation is shown to exist, it is obvious that more detailed analytical work and additional instrumentatinn are necessary to explore the modes of vibration, the critical frequencies and to identify the sources of excitation.

3.3.2 In-flight Measurements

To support and substantiate results of collimator measurements, the mounting of sensitive accelerometers at critical points in the camera system should be considered. It is unreasonable to expect tape recorded data of this sort, but real time transmission during a limited number of engineering passes over tracking stations is probably adequate. Also during engineering passes it should be possible to correlate gas valve firings from telemetry data with individual camera frames and attempt to compare photographic quality during periods of intense gas valve activity with that during periods of no activity. To obtain a similar correlation during operational passes requires some technique for recording the valve firings. Again tape recording appears unreasonable because of the frequency response requirements, however, it would appear

feasible to record directly on a film data block if preliminary testing indicates that this is a critical area.

CONCLUSION

The program described above represents a very costly effort, and no guarantee can be made at the outset that serious photographic degradation exists as a result of these factors and that it can be identified and corrected as a part of such effort. Additional emphasis on more and better instrumentation on operational flights might be used as an alternate approach to piece together the total picture over a longer period of time, assuming that a usable measure of operational image quality will be available and that other degrading effects can be measured and factored out. The cost of the test effort must be weighed against the desirability of determining objectively the extent to which these particular factors degrade the photographic output of the Cm system, recognizing that some degradation almost certainly is present and that existing data ~~is~~ are inadequate and inconclusive in terms of establishing the magnitude of such degradation.